Autopoiesis and the evolution of information systems

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ABSTRACT

In this paper we explore the relevance of the theory of autopoiesis for understanding the evolution of information systems. We use the theory as a metaphor which highlights three themes: (1) How systems construct their own environments, (2) how the system's organization of itself and its environment shape the conditions for their success and failure, and (3) how systems deal with changes that are destructive to their identity. Evolution in this perspective is seen as the construction and maintenance of an identity instead of adaptation to external changes. The environment only exists through perception and is organized in such a way that it facilitates the reconstruction of the identity. The theory draws attention to the dynamics that constitute the process of evolution, instead of focussing on the outcome of processes of evolution. We illustrate these ideas by describing a case study of an information system that remained relatively stable over a period of thirteen years in a context of massive changes.

Keywords: Information systems, evolution, change, autopoiesis.

1. INTRODUCTION

The relation between organizational change and information systems (IS) has received much attention in the information systems literature. Much of this research has concentrated on the effects of organizational change on information systems and vice versa. Such research has generated rich insights in the facilitating as well as constraining role of information systems in the process of organizational change. Many analyses assume a distinction between the system and its environment, the organization. Information systems are seen as being relatively stable entities while the environment is a source of change and uncertainty. Such a perspective stresses the need for a continuous adaptation of the information system to its dynamic environment.

In this paper we challenge this conception of the relation between information systems and organizational change by outlining a perspective that focuses on the process of evolution itself that leads to the effects commonly researched in the IS literature. This reflects a wider interest within the study of information systems and organizations that calls for a richer understanding of the generative mechanisms through which information systems and organizations evolve. Evolution, in this view, is not conceived as a trajectory of improvement, which leads to a desired end-result through several phases but as a process of which we need to explore its inner workings. We then might develop a richer

insight as to how and why information systems and organizations change and stabilize, irrespective of the effects they produce.

In this paper we draw on the theory of autopoiesis, a recent biological theory which sheds new light on the evolution of living systems and which might be relevant for the evolution of information systems as well. In this theory the common relation between a system and its environment is blurred. The environment only exists through perception, and thus is part of the system. Change, in this view, is generated internally and evolution is not a process of adaptation but of maintaining the system's self-identity. We attempt to apply the ideas of autopoiesis metaphorically to the evolution of information systems, which we illustrate with an empirical study, and we present some theoretical implications of this perspective.

The next section presents a short overview of autopoiesis with respect to the issues that are relevant for our purposes. In the third section we will outline how we use autopoiesis for the analysis of the evolution of information systems. The ideas that are metaphorically derived from this theory are illustrated in the fourth section by drawing on a case study of the evolution of an information system over thirteen years. Subsequently we analyse the case by drawing on autopoiesis and discuss our findings in the light of contemporary social theory. In the sixth section we end the paper with the conclusion that autopoiesis opens new and interesting lines of thinking about change in and of information systems.

2. THE THEORY OF AUTOPOIESIS

Maturana and Varela have formulated the theory of autopoiesis in the early 1970s as an explanation for the nature of living systems (Maturana and Varela 1980). The term autopoiesis is adopted from Greek and means self-production. The theory is a new approach to systems thinking. The central idea of autopoiesis is that living systems produce themselves. The system's components and processes jointly produce the same components and processes, thus establishing an autonomous, self-producing entity (Mingers 1995). Autonomy of a system is the key feature of living beings and refers to the ability to specify what is proper to it (Maturana and Varela 1992). The mechanism that makes living systems autonomous is autopoiesis.

The recognition of the autonomy of a living system implies that the traditional distinction between a system and its environment is no longer valid because an external observer makes such distinctions. Instead, autopoiesis poses that a living system continuously constitutes its own boundaries, it perceives its surroundings (which Maturana and Varela call the medium) in its own ways, thereby constructing an environment. In Varela's words: "[W]e are becoming more and more interested in an epistemology which is not concerned with the world-as-picture, but with the laying down of a world." (Varela 1984). In explaining the workings of the human brain for example, Maturana and Varela say that the brain produces images of reality which are determined by how the brains themselves are structured. In other

words, the patterning of the brain determines the perception of the world. With those images interaction occurs that may lead to changes in the organization of the brain, depending on the actual experience. In this sense, the environment is not 'something out there' but it is actively constructed by the system itself as part of its own organization. Hence, the environment needs to be seen as part of the system. Although a living system operates in a physical environment, the relation to that environment and the interaction with it is determined internally. Thus, for example, certain berries are poisonous for human beings. This is, however, not the intrinsic property of the berries but dependent on the physical properties, i.e. the organization, of the human being. For other living systems, certain birds for instance, the berries may not be poisonous at all.

In maintaining autopoiesis the identity of a living system is of central importance, and all activity is meant to preserve this identity. All interaction which the system is engaged in is meant to reinforce or reproduce this identity. Patterns of interaction are circular and part of the system's organization. An important characteristic of autopoietic system is that they are organizationally closed systems, meaning that all possible states of activity must always lead to or generate further activity within the system (Mingers 1995). Or, to put it differently, all activity must maintain autopoiesis to prevent the system from disintegration. The environment, which is created by the system itself, is therefore a projection of its own identity. The way the world is seen by the system is determined by the system itself, instead of being a reflection of an externally existing order. Living systems thus close in on themselves to maintain a stable pattern of relationships that are self-referential. The interaction of the system with its environment is always self-referential in the sense that it refers back to the system's identity in order to facilitate self-production, i.e. to maintain autopoiesis.

If living systems strive to maintain autopoiesis and relations with the environment are determined internally, then systems can evolve and change only along with self-generated changes in identity (Morgan 1986). The theory of autopoiesis perceives the evolution of living systems as a result of internally generated change. Rather than suggesting that the system adapts to an environment or that the environment selects the system that survives, autopoiesis places its emphasis on the way living systems shape their own future.

Changes in the system are only triggered from outside. What the eventual change will be and even what in the environment can or cannot act as a trigger both is determined by the actual living system. The changes that an autopoietic system can undergo are determined by the individual system so long as autopoiesis is maintained (Mingers 1995). Living systems "are organized in such a way that their processes produce the very components that are necessary for the continuance of the processes" (Mingers 1989). Maintaining autopoiesis is not just the reproduction of the same characteristics in similar circumstances, but rather the production of subsequent elements different from previous ones. However, the state of the actual system at a given time will determine the actual changes that the structure undergoes. In autopoiesis this is known as structurally determined. The internal structure

that determines what changes are possible to occur -only those that maintain autopoiesis- and thus how interaction with the environment will trigger changes in the system.

3. AUTOPOIESIS AS A METAPHOR FOR INFORMATION SYSTEMS

The application of the theory of autopoiesis, which has originated in biology, to the realm of the social is subject to controversial opinions. Maturana and Varela have refuted the idea that social systems are autopoietic. Some have suggested that social systems often portray characteristics similar to those autopoiesis explains in living systems, such as autonomy and the persistence of identity in contexts of massive change (Mingers 1995) Opinions on the applicability of autopoiesis to areas other than living systems - such as groups, organisations or society, seem to differ (Mingers 1995, Brocklesby and Mingers 2005; Huysman et al 1995; Seidl and Becker 2006). Some have directly applied the theory to social systems or have tried to slightly alter the theory of autopoiesis to fit the social as well. Influential has been the work of Niklas Luhmann on social systems as being autopoietic and in which communication plays a central role in the process of self-production (Luhman 1986; Seidl and Becker 2006). The book by Von Krogh et al (1995) brought the theory in relation to knowledge management issues.

We share the concerns about the direct applicability of autopoiesis to social systems and we support Kickert's remark that "...it is not so important whether a useful idea is an accurate translation of the original natural scientific model, but rather whether the idea is interesting and relevant..." (Kickert 1993). In order to explore the relevance of the theory of autopoiesis to the area of information systems we use the theory as a metaphor. has been successfully exercized and embraced in the fields of organization theory and information systems (Morgan 1986; Walsham 1991).

The use of autopoiesis as a metaphor for information systems questions common conceptualizations of information systems. Traditional views on information systems are rooted in a mechanistic paradigm based on cybernetic systems thinking while the increased attention to social issues call for ways of thinking beyond this 'dead paradigm for living systems' (Ray 1993; Blonk 2002). In this paper we follow Kling's conceptualization of an information system as a web of computing, a perspective that explicitly includes the social, historical and political dimensions of the system besides the focal technology. Information systems "are not only flexible information processing tools [but] their 'shape', the way they are used, the leverage they provide, and the interests they serve depend upon the interplay of stakeholders, resources, and social games within which they are deployed." (Kling 1987). So, information systems are not just neutral entities, but they embody procedures, routines, power structures, and so on. They pre-select action, relations and possibilities. They embody 'how things are done around here', they have an identity.

In the next section we describe a case study of an information system that clearly acquired such an identity. It embodies how things were done one way rather than another. And its evolution shows a tendency to maintain itself, to keep up its identity regardless of its dynamic surroundings. The case shows that it was not just the hardware and

the software, but also the social groups involved, the structures that were created, the style of thinking and the way of managing that preserved the system as a whole. This whole socio-technical ensemble is what we attempt to analyze as if it were autopoietic. A system that continuously constituted its own boundaries, seemed to have acquired a high degree of autonomy, and was actively involved in reproducing and thus maintaining itself.

4. METAPHOR IN MOTION: A CASE STUDY

The case tells us about a financial management information system at the Dutch Railways, which was developed in 1981 and continued to exist until 1993 (a more extensive version of the case has been published in Van der Blonk 2002). The life of this system is described parallel to a massive process of change at the Dutch Railways which, in this period, was transforming from a state-owned and open-end financed corporation to a privatized and commercial business. Within the context of these massive changes the financial information system continued to exist despite the 'match' with its organizational context was lost. Seen in retrospect, it raises the question how a system that increasingly did not fit its environment anymore continued to be supported and financed, and was even redeveloped. For this, we need to understand the historical context of the organization and how it responded to change.

The Dutch Railways is an old organization, which traditionally has been a state-owned company. Before approximately the 1980s the organization had been quite stable even though in the 1970s the Dutch Railways have seen an enormous expansion of the organization, its infrastructure and its activities. The organization had developed quite a strong culture, which provided the members of the organization security and stability. Employment was life-long, and salaries and fringe benefits were good. The organization itself was hierarchical and administration and staff were centralized at the head office. The regional units of the organization mainly were concerned with the operational processes to keep the trains running, such as personnel scheduling and maintenance work. The strong position of the unions and importance to acquire status and resources (which was dependent on number of employees) made personnel issues a very central focus. Financially, the organization was open-end financed, which meant that all costs were accounted for by the Dutch government. Especially in the period of expansion of the 1970s expenses had grown enormously which in fact started the process of restricting expenses - a process which would unfold into different successive ways of financial management and eventually in the privatization of the Dutch Railways in the 1990s.

Around 1980 the Dutch government decided to cut expenditure on the Dutch Railways by introducing yearly budget-limits. As a consequence, the organization was restructured into a flatter organization with more regional units and decentralization of responsibilities. The position of the regional accounting departments gained much in importance; parts of the financial administration was now carried out regionally and the head of the department became member of the regional management team. In this context, the head of the central department of Planning and Control initiated a project to develop a new method of registrating costs and providing management information. This New

Accounting Method (NAM) was meant to support the new budget-based organization, but the motivation to develop this method and its supportive system was more comprehensive; it also was an attempt to introduce a certain style of management based on personal as well as professional grounds, as the former head of the central department of Planning and Control states:

"It was purely my initiative. It was my opinion we would have to do this and that we should do this. There was no decent instrument for financial management available."

To realize the initiative, the head of the central department of Planning and Control hired an accountant and consultants who designed the basic structure of the system. A project group was started to further develop the system and to implement it in every regional unit. Young professional assistants were hired and trained to implement and use NAM. Every assistant was assigned the task to take care of the implementation of the system in the regional unit in which they were given a permanent position within the accounting department. The system was a revolution because for the first time costs of operational processes were identified, registered and managed. The project group worked under the supervision of the central department who could decide how the system was modified and further developed. In 1984 the system can be said to be implemented in every regional unit but several regions showed quite some resistance. An important reason for this was that regional management disliked the fact that NAM made decisions financially transparent, as a former accountant notes:

"The head [of the regional accounting department] wasn't a very popular guy; somebody who was always harping on the money. By then, it was not very common to talk about money".

Further, the system, which still was manual, appeared to involve much work of a labour-intensive and simple calculative nature. A first attempt to automate the system failed because of technological reasons. A spreadsheet appeared not to work on one of the first IBM PC's when the data of the NAM system was entered. A new head of the central department of Planning and Control, somebody who also was involved in the development of NAM, asked the central IS department to design and build a computer-based system to support NAM. Although that system, called NAMIS, took over much of the routine work, the underlying method of NAM was not changed.

In 1988, not too long after the automated system was introduced, the budget structure was changed into what was called 'contract management'. Instead of the Dutch government setting budget limits (which could be exceeded), the Dutch Railways were now required to plan their expenditures in advance thereby estimating the budget needed. The proposed budget was then recorded in a sort of contract between the Dutch government and different levels of management. The context in which the system was designed and operated had now changed quite significantly in nature. NAMIS was designed to registrate and allocate costs and produce management information based on the recorded data. It was not designed to support the planning of expenditures a year ahead in order to determine the

budgets needed. NAMIS also suffered from some functional shortcomings and rigid features, which had resulted in resistance and dissatisfaction with the system. Users had developed extensive procedures and routines to cope with the system's rigidity and restrictions in order to do their work properly. This, then, was the background for the initiative to rebuild NAMIS. The project team, which did an initial study in 1990, concluded that NAM and its underlying logic should be maintained. The problems were identified in obsolete computer equipment, functional shortcomings and mistakes, and inadaptability to local requirements. Solving these problems by rebuilding the system was seen as the way out.

Also in 1990 the organization, again, was restructured. The 15 regional units were grouped together into 8 larger units and were given significantly more autonomy. Each region thus formed its own management team, and several new managers and controllers were hired, some of which came from outside the organization. Also, a controller from corporate level replaced the head of the central department of Planning and Control. Several newly formed regions started to develop their own information systems accordingly to their own views and needs, as a former controller remarks:

"New managers in the regions with new controllers, often not from the original organization. Everywhere the wheel was re-invented, and everywhere different."

Shortly after the new organization was implemented the new head of the central department of Planning and Control had to decide whether or not to continue the project of rebuilding NAMIS, which history he was not familiar with. Several regional controllers under his supervision (who had been involved in the development and implementation of NAM) were in favour of the continuance. The decision was taken to continue the project as the head of the central department of Planning and Control comments:

"Was the system bankrupt in peoples minds? Of some, yes. But surely not of everybody. [We continued the project because] otherwise you have nothing, then you don't know what happens out there, what kind of costs are being made."

Parallel to the start of the new organization the project to rebuild NAMIS continued from early 1991 onwards. The project team consisted of IS professionals and a small group of users who were selected by the project leader. Most of the participating users were already familiar with NAM for a number of years. During its development the system was presented very attractively to the organization - proposed future users could engage in a prize contest to give the system a name, a logo for the system was designed, frequent newsletters were distributed, and an expensive looking manual for the NAM-method and the new information system were distributed among the users. In the meantime the 'old' NAMIS was still supposed to be used in the regions until the new system was ready. But the actual situation was very different. Several systems were being developed in different regions and even the central department of

Planning and Control started projects for a new financial management information system. These systems were based on the new organization and the information requirements it imposed. However, they also were alternatives for the NAM and its supportive information systems. One region produced management information reports for the central departments using their own systems to generate the information and a word processor to imitate the layout of NAMIS reports.

The project to rebuild NAMIS suffered from a number of drawbacks: The formal description of NAM had been lost and needed to be rewritten, there were performance problems and a conflict with the supplier of the system delayed the project. The system was introduced in 1993, approximately two years after the reorganization and nearly four years after the project was started. During the implementation and user training the team noticed serious resistance. Two regional units refused to implement the system and a third wanted to postpone the implementation for one year. Subsequently, the general manager forced the regional units to implement the system. Even though the system was technically implemented it has never successfully been used. One and a half year later, when the data for this research was collected, the department formally responsible for maintaining the system didn't have a clue who were still using the system, and they were very surprised to hear that some are still working with it.

Yet, years after the collapse of NAM and its computer-based versions several people view the system as a good system that should have been used still today. The problems are not in the system, but in its environment - the organization, they say:

"[If you watch the developments now] there's nothing new. What we introduced in '84, the organization might be ready to work with it. But it required two expensive information systems to get there. What is now presented as new or innovative, is just a revival if you've been in it long enough" (a former project member)

"[NAM] could have been extended and changed into a system that still would have been used. Then it would have been the current system. But we went through a different line of developments; they blew it, the reorganization, no support from management, everybody wanted their own system - and now again there is a trend toward a uniform system. The same result, but just a different path." (Former controller 1)

"The whole idea behind NAM is still alive and present in today's systems, but it is experienced as something totally new. It's so crazy, so funny. People who have never known NAM end up with the same sort of ideas. And that's quite nice to notice." (Former controller 2)

5. ANALYSIS AND DISCUSSION

The metaphor of autopoiesis opens up an interesting and alternative perspective on how information systems evolve. It provides a view of information systems as social systems of interaction or social webs (Kling 1987), which continuously try to maintain their self-image. In the theory of autopoiesis the identity of a system plays a central role and is continuously reproduced through the mechanism of autopoiesis. In contrast to more common perspectives on the evolution of information systems that stress the successive stages or states in a line of development, this metaphor draws attention to dynamics of the process how systems evolve, and to what it is that is evolving. The emphasis, in other words, is not on the (successive) outcomes, but on the underlying process that generate these outcomes.

In analyzing the case using this metaphor, three themes are highlighted. First, how it is that a system creates its own environment and constitutes its own borders; second, how the organization of the system and its identity determine the conditions for its own functioning whether that will be success or failure; and third, how a system deals with changes and developments which are a threat to the system's continuity. We discuss how the described information system constitutes itself as an autonomous and organizationally closed system aiming at the continuance of its very existence. We try to link the insights from autopoiesis to some literature in organization theory and information systems.

The first implication is that an information system continuously organizes itself including its perception of the organizational environment. It organizes its environment in such a way that the identity of the system will fit the whole framework of perception and vice versa. The system enacts its environment by distinguishing only those aspects that make sense to the system, and it tends to ignore all that does not make sense to the system. The system thus decides what is relevant and what not, it imposes a structure upon its surroundings that makes sense to the system itself, and it engages in self-referential interaction with its surroundings so that it is able to relate to perceived developments in order maintain itself. In this way the system establishes itself as an autonomous and organizationally closed system that determines its own boundaries, and selects what is proper to the system. Let us now assess how this happened in the described case study.

The case portrays not just the development of a new method, but also of the socio-institutional set-up, which was needed to let the system function. After the system had been developed it was implemented in every region by newly hired assistants who were supposed to take care of the implementation at each site. Most of those new assistants later became controllers and entered an even better position to preserve the system. In order to establish itself, or to realize its identity, the system organized and created its own environment. Further, the introduced method itself is a way of organizing the environment because it discerned a large number or organizational processes, and how they needed to be financially measured. This perception of the organization was recorded and reified in formal descriptions of the NAM method, elaborated user manuals were distributed in which organizational processes and the according financial management information were specified. With the introduction, the regional units were made familiar with the system, i.e. the units were learned to view the organization as was pre-structured by the system, and which not

always was the preferred perception of the regional units themselves considering the resistance that was exhibited. Such documents and training programmes reflect the system's view and understanding of the organization, as well as its interests, which apparently closely linked to those of the accountants and controllers. As time went on the system further actively organized its environment by introducing computer-based information systems that embodied the method and took over much of the administrative work. This is to be seen as a process of institutionalizing this particular way of organizing so that the system could maintain itself.

The next issue which is raised by embracing the metaphor is what it is that is evolving, what is the identity that is reproduced, and how? The identity of the system determines how the system is organized, and the stability of the organization enables the system to reproduce itself. Autopoiesis thus refers to a duality between the structure of a system and what it aims to be. This is a recursive process in the sense that changes in the system's organization have to cohere with the system's identity. They are not separable, but evolve alongside. The process of organizing is the realization of an identity; both a system's identity and its organization including its perception of the environment is the subject of evolution. Therefore, the system creates its own conditions for evolution; it shapes its own future.

In the case, the identity of the system is the world of thought on which the system is based, and which is embodied in the system. This self-image of the system was continuously maintained and reinforced through self-referential processes. It contains a set of values, and patterns of thinking, a preconceived structure of this particular part of the organization of the Dutch Railways, and it is most clearly reflected in the three statements at the end of the case description in the previous section that talk of the ideas, the world of thought behind the system. Even though the computer-based information system had failed and NAM was no longer used as a system, people interpreted the world of thought behind the information system still as present and relevant, although it was realized in different systems. The identity was further emphasized and constructed through the prize contest to give the system a name and the logo that gave the system a face. The system was recognizable. A system needs to have such a cultural identity in order to deal with insecurity, uncertainty and anxiety that are inherent in social life Gagliardi 1986). A system may give people (who are 'in' the system) a sense of identity; a framework of theory, values and related technology that enables people to make sense of their roles in the system (Schon 1971, Gagliardi 1986). This, at the same time forms a condition for the maintenance of the system's very identity. The system in our case study clearly involved people who continuously supported it, and were being involved in the maintenance and redevelopment of the system. During data collection some people spoke of 'die-hards' who kept on supporting the system, and one of the project members, very convinced, said: "It is my system."

The cultural identity and the system's organization shape the construction of opportunities and threats; it determines how a system perceives what is to be seen as threats and opportunities. Problems, crucial developments, priorities etcetera, in this perspective, are closely linked to the identity a system wishes to maintain (Morgan 1986). In the case of NAM, the strong tendency to maintain the cultural identity of the system prevented it from incorporating the wider

developments in the organization, and shaped the conditions for failure. An interesting perspective on the strive for stability in social systems and its resistance to change has been described by Schon in his book Beyond the Stable State, as what he calls "'dynamic conservatism' - that is to say, a tendency to fight to remain the same." Schon acknowledges that resistance is inherent to social systems: "Resistance to change does not come from the stupidity or venality of individuals within the system; it is a function of the system itself." (Schon 1971). He thus points to a similar characteristic of social systems as autopoiesis points to in living systems, which is the tendency to fight to remain the same.

The question is how social systems deal with threats and disruptive changes that may cause destruction of the system. Schon discusses five strategies how social systems exercise dynamic conservatism, i.e. how they deal with changes that disturb the stable state, or to put it different, how they engage in the process of maintaining autopoiesis. First the system tries to ignore the presence of a threat, and if it can not be ignored it launches a counter attack or a preventive attack before the threat has materialized. If it does not succeed, it allows the threatened change a limited scope of activity and keeps it isolated. The fourth strategy is to absorb agents of change and turn to their own ends the energies originally directed towards change. And finally, if even that appears not to work, the system changes, but it allows the least change capable of neutralizing the intrusive process. The sequence of the first three strategies we clearly recognize during the process of rebuilding NAMIS. The changes in the organizational environment were ignored at first by keeping on using the same system. When it appeared that the changes could no longer be ignored, developments were attempted to be countered by redeveloping the NAMIS system. However, the developments were interpreted as a reason for optimizing the existing system without questioning the underlying method and assumptions, thus in such a way that the system's identity could be maintained. But the changes embodied in the new organizational structure and new systems were of a different nature and could not be ignored. The system appeared not able to adopt the fourth and fifth strategies, at least not in time, and it was abolished.

6. CONCLUSION

In using the theory of autopoiesis as a metaphor to analyze the evolution of information systems we were able to draw attention to the generative mechanisms, the underlying dynamics that determine the continuity of a system. We have seen that a system is able to create its own conditions to be successful, or alternatively for its destruction. Autopoiesis, when used as a metaphor, may provide us with an interesting perspective on the process of evolution of information systems. The interesting insight this approach offers, and which was illustrated in the case, is that the main aim of systems is to maintain their identity despite the changes in their surroundings, in contrast to the common view of evolution as adaptation to external changes. It draws attention to how the system is structured to view the world rather than the way the world 'is' (Walsham 1991). This is not to say that such systems are static but rather that their evolution is determined by the identity the system has gained. Consequently, the evolution of information systems can be characterized as self-referential, autonomous and organizationally closed.

The theory does however also have its disadvantages of which we should be aware when using the theory for social systems (Walsham 1991; Morgan 1986). Organizational politics and issues of power are fully ignored. For example, the powerful position of the central department of Planning and Control in relation to the relatively weak position of the regional units has formed an important reason why NAM could diffuse itself through the organization. Also the decision to continue the redevelopment of NAMIS and its later introduction included negotiation, politics and the use of power. Besides that, autopoiesis in the tradition of systems theories stresses unity as opposed to plurality and conflicts, which often seem to characterize social behaviour and organizations (Walsham 1991). But maybe that is the point where the metaphor loses its power. So far, we think it has proved a useful way of thinking about the evolution of information systems.

Future research should further explore the underlying dynamics of the process of change, in order to enhance our understanding of how systems are (and should be) constructed, and how they evolve. Only then are we able to explain successes and failures of systems, because both success and failure are the results of the same underlying dynamics.

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